Evaluation of Alternatives to Reservoir Lowering Start Date from Those Proposed in November 2006 Federal Energy Regulatory Commission Report

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Introduction

The Coastal Conservancy outlined a proposed Klamath River dam removal approach in a report filed with the Federal Energy Regulatory Commission (FERC) in 2006. That report, by Gathard Engineering Consulting, presented a scenario in which the four lowermost dams would be removed concurrently, beginning with reservoir drawdown in October.

Adverse effects caused by drawdown-triggered high total suspended sediment (TSS) levels have prompted a reconsideration of drawdown start-time. This update investigates alternatives to initiating the lowering process during the October low flow regime. The purpose of this analysis is to provide information that will help assess relative benefits and risks of alternative removal schedules. The analysis provides results of TSS duration, intensity, and timing by varying parameters that determine these results such as start date, historical flow records, drawdown rate, and outlet capacity.

This update to that earlier report provides new analysis and responses to concerns raised by resource managers regarding the timing of reservoir drawdown under the earlier proposed dam removal scenario.

Drawdown of reservoirs is an essential precursor to dam removal. The most recent concerns raised by resource managers involve the timing of released sediment during reservoir drawdown. More specifically, some resource managers have indicated that the previously selected window for drawdown may conflict with key migration periods for migratory fish species. This update summarizes assumptions of the earlier study; addresses recently raised concerns; provides an overview of study assumptions, and; presents possible drawdown alternatives.

The total suspended sediment (TSS) analysis in the 2006 investigation was based on lowering reservoirs at 3 feet per day, the most rapid rate of lowering the reservoirs advised by engineers without further geotechnical investigation, and eroding sediment during the lowest flow of the year to minimize the duration of high suspended sediment and turbidity events. This approach, as recommended by resource agency participants in initial coordination meetings, sought to abbreviate the period of high TSS levels resulting from drawdown, and to limit high pulses to one rather than multiple events. Due to low flows during the proposed drawdown period, the reservoirs would be completely evacuated during the initial lowering process. During the period when the reservoirs are drawndown from full to completely empty the river flow would erode most of the sediment in its path and create a new river channel in the predam river banks. By lowering the reservoirs during the low flow period, starting in October of the year, the time required to lower the reservoirs would be minimized because during this period the flow into the reservoirs is always smaller than the flow capacity of the low-level outlets.

Conversely, during other times of year, inflow can exceed the flow capacity of the low-level outlets.

The earlier report recognized that flow capacity of the proposed and existing low-level outlets was not sufficient to keep reservoir elevations at a minimum level during the following winter high flow season. Late fall and winter high flows would refill the reservoirs to varying degrees based on inflow because of limitations of outlets to pass the full river flow. By eroding the sediment prior to the high flow period it was assumed that the subsequent spring drawdown of the refilled reservoirs would not create high TSS levels because the sediment would already have been eroded.

The October drawdown approach was designed to cause the majority of reservoir sediment erosion to occur during the initial lowering of the reservoirs and to minimize the duration and intensity of suspended sediment in the following spring and summer as the reservoirs elevations were again lowered. Similarly, the October drawdown approach was designed to avoid multiple sediment pulses. Under the October drawdown scenario, most of the erodible sediment between the river banks in the reservoirs would have been eroded during the initial lowering, later high flows which would increase reservoir elevations and the subsequent re-lowering would not cause significant sediment erosion.

Methodology

A computer model was developed to provide a conceptual level evaluation of the alternatives to initiate reservoir lowering beginning in October as presented in the GEC report of November 2006.. The model connects three reservoirs in the Klamath River Project (Iron Gate, Copco I and J.C. Boyle)[1] by routing flow and sediment from the upper through the lowest reservoirs. The model allows for analysis of the effects of reservoir drawdown using variable conditions and assumptions including: start date for initiation of reservoir lowering; water year; river flow conditions (using historical flow records); volume of sediment eroded; rate of reservoir elevation lowering, and; low-level outlet capacity at the dams.

The volume of sediment eroded was not varied in this analysis because start date and lowering rate do not affect eroded volume. Reservoir sediment trapping and re-erosion of trapped sediment are analyzed in the model as a function of river flow and reservoir elevation. River flow records at Iron Gate and J. C. Boyle dams from water year 1962 through 2006 were used in the analysis. Pre-dam river width was used for the minimum river width with initial bank failure slopes at a minimum of 10 to 1. The average river width using this approach is only slightly wider than the pre-dam width to accommodate some overbank erosion.

Reservoir Lowering Start Date

Klamath River average daily flow records show that the lowest flows of the year occur starting around the beginning of October and extend as late as January for some years. The model allows initiation of reservoir lowering at any time of the year. A start date of December 1st was used in this most recent analysis. The later start date means that average river flows are higher than in October. Higher flows can result in slower rates of lowering the reservoir, which in turn extends the duration of sediment erosion and adverse impacts associated with the suspended sediment. Figure 1 and Figure 2 compare the effects for a high flow year on TSS intensity, duration, and timing. These figures illustrate the higher frequency of TSS events in the spring of the year following the start of drawdown when drawdown starts at a later date. Figure 8 through Figure 19 show TSS results for high, average, and low flow years. These figures illustrate the higher incidence of high TSS events in the spring and early summer for high flow years compared to average and low flow years.

Outlet Facility Considerations

The GEC report discussed the objective of lowering the reservoirs as rapidly as possible to reduce duration of high TSS levels. The opening size of low-level outlets at Copco 1 and Iron Gate dams limits the rate of flow out of the reservoirs and the rate at which the

[1] Copco II is omitted from the model due to size and absence of sediment.

reservoirs can be lowered. High flow years typically produce river flows that exceed the capacity of the existing outlet tunnel at Iron Gate dam. No low-level outlet currently exists at Copco 1. The removal design proposed in the GEC Report included constructing a 10-foot by 10-foot tunnel through the bottom of the concrete Copco 1 dam. That tunnel size was developed to allow Copco 1 reservoir to be lowered at a rate of over 3 feet per day during the month of October for most years. For the alternatives that initiate the withdraw on December 1st, a larger tunnel with an opening approximately twice as large would be necessary to maintain a lowering rate consistent with the maximum rate at Iron Gate Dam. For high flow years, lowering Copco 1 at the same rate as Iron Gate would reduce effects of sediment erosion and TSS later in the water year. Figure 3 and Figure 5 illustrate the duration and intensity of TSS in late spring during high flow years for larger and smaller Copco 1 outlet facilities. Figure 4 and Figure 6 shows the difference in water surface elevation at Copco 1 for the larger and smaller outlets. Further review of the structural effects of a larger tunnel through Copco 1 will be required to determine the feasibility of constructing a larger low-level outlet. Cost of tunnel and outlet gate controls will increase if a larger tunnel were constructed.

River Flow

Records for average daily flow at Iron Gate were used to rank the 45 years of record from 1962 to 2006 used for this analysis. Total yearly flow volume was used to rank each water year with the lowest flow as number 1 and the highest flow as number 45. To assess the effects of flow on the frequency of high TSS events in the spring and summer, the number of days after May 1st that high TSS occurred was counted for each flow year using a reservoir lowering start date of December 1st. As illustrated in Figure 7, higher flow years, as indicated by the higher ranking of the water year (WY), correlate with higher number of days counted with high TSS after May 1st. This analysis was conducted using an outlet size at Copco 1 similar (opening area approximately 200 square feet) to that of Iron Gate so that both reservoirs could be drawndown at approximately the same rate. A rate of 3 feet per day was used for the analysis shown in Figure 7.

Rate of Reservoir Drawdown

As discussed above, faster rates of reservoir lowering would reduce the duration of TSS and the number of days that high TSS events would occur in spring and summer months. The maximum rate of reservoir lowering is controlled by the stability of the reservoir canyon walls as the reservoir is lowered and by the capacity of the low level outlets to pass flow, as discussed above. The GEC report discussed the maximum rate of lowering as restricted by canyon rim wall stability considerations. For the FERC report three feet per day was used as the maximum rate of lowering for analyzing TSS levels. The Conservancy is proceeding with additional geotechnical studies to assess the ability to increase the rate of lowering based on reservoir rim stability considerations. Analysis shown in Figure 8 through Figure 19 was conducted using a maximum rate of lowering the reservoir of three feet per day.

Several higher reservoir lowering rates were analyzed to determine if TSS events could be eliminated entirely after May 1st for all years of record. For a typical high flow year, WY 2006, lowering the reservoirs at three feet per day caused 16 days of high TSS after May 1st. Lowering the reservoirs at 10 feet per day would eliminate high TSS after May 1st. However, it is unknown if a 10-foot per day drawdown rate is advisable from a geotechnical standpoint.

For all years, approximately 20% of the 45 years of record experienced more than 1 day of high TSS after May 1st when analyzed at a rate of reservoir lowering of 10 feet per day if lowering were started on December 1st. Therefore, increasing the reservoir lowering rate to the rate of 10-feet per day failed to eliminate occurrence of high TSS after May 1st, but did significantly reduce the number of days that high TSS events occurred.

Reservoir Sediment Trapping and Sediment Re-erosion

The reservoir model analyzes the effects of trapping sediment and re-erosion of trapped sediment. Flow into Copco 1 from J. C. Boyle and into Iron Gate from Copco 1 will contain suspended sediment that will be trapped in the lowermost reservoir. Trapping efficiency decreases with higher flows and lower reservoir elevations. Approximately 72% of the suspended sediment entering the reservoirs will settle in the reservoirs when reservoirs are full. The portion of the trapped sediment that settles in the river channel will later be re-eroded as the reservoirs are lowered. The model distributes the trapped sediment over the remaining reservoir areas based on the elevation at the time the flow enters the reservoir. The portion of the sediment in the river channel for each elevation is re-eroded when the elevation of the reservoir reaches a lower elevation than previous elevations. The portion of trapped sediment that is re-eroded varies from 22% for the full reservoir to 100% at the lowest reservoir elevations. More discussion of the trapping and erosion is contained in the attached discussion of model assumptions.

Findings

- Starting reservoir drawdown later in the water year (WY) causes more high TSS events in the spring and summer of the following year than starting in October. Starting reservoir lowering at the beginning of December of the year does not allow the reservoirs to be completely drawndown until spring of the following year in most years. If reservoirs are not completely drawdown in the autumn of the year, subsequent lower reservoir elevations in the spring and summer of the following year will create high TSS events. Only 3 of 45 years investigated had no high TSS events after May 1st of the following year if reservoir drawdown was started in December and the maximum drawdown rate was 3 feet per day.
- A significantly larger outlet at Copco 1 would be required to allow Copco 1 reservoir to be lowered at the same rate as Iron Gate for higher late fall flows. The feasibility of

creating a larger outlet facility at Iron Gate Dam would require extensive analysis and is beyond the scope of this investigation. A larger Copco 1 outlet reduces the frequency of high TSS events in spring and summer of the year following the start of reservoir drawdown, but does not eliminate altogether the potential for high TSS events in spring and summer months following reservoir drawdown.

- The rate of reservoir drawdown is limited by dam safety considerations, canyon rim wall stability, and outlet flow capacity. A higher rate of reservoir drawdown could significantly reduce the number of days of spring and summer high TSS even in high flow years, but would not eliminate them. The maximum allowable drawdown rate supported by future geotechnical analysis would dictate the number of spring and summer high TSS events.

Conclusions

A computer model connecting the three reservoirs, Iron Gate, Copco 1, and J. C. Boyle, was developed to predict suspended sediment discharge timing and intensity resulting from reservoir drawdown at the four lowermost Klamath River dams. The model provides an initial assessment of the possible suspended sediment levels in the river downstream of Iron Gate Dam resulting from lowering the reservoirs. The model allows the drawdown rate, size of Copco 1 outlet opening, the start date of lowering, and the water year to be analyzed as separate variables.

The analysis found that starting the lowering of the reservoirs on December 1st, leaving Copco 1 outlet opening size at the originally proposed level, and lowering the water level at 3 feet per day, as discussed in the November 2006 FERC report, resulted in numerous late spring and summer high TSS events for most of the 45 years of record. Doubling the Copco 1 outlet facility opening size would increase the flow capacity to approximately the same as that at Iron Gate Dam, and would reduce the number of spring and summer high TSS for all scenarios relative to opening size proposed in the GEC Report.

Increasing the rate of lowering the reservoir was most effective at reducing late spring and summer TSS events. At the maximum rate investigated of 10 feet per day only 20% of the years experienced high TSS after May 1st of following year. Increasing the size of Copco 1 outlet, increasing the reservoir lowering rate to 10 feet per day, and starting the lowering on November 1st eliminated high TSS events in all but 3 years. In those three years that did experience high TSS in spring or summer, none experienced more than a total of three days during that period. This may be an acceptable level of risk to justify a later drawdown start date.

A combination of high reservoir lowering rate, an earlier drawdown start date than December 1st, and increased outlet size at Copco 1 can significantly reduce the probability that high TSS events will occur from lowering the reservoirs but not completely eliminate that possibility.

Model Results

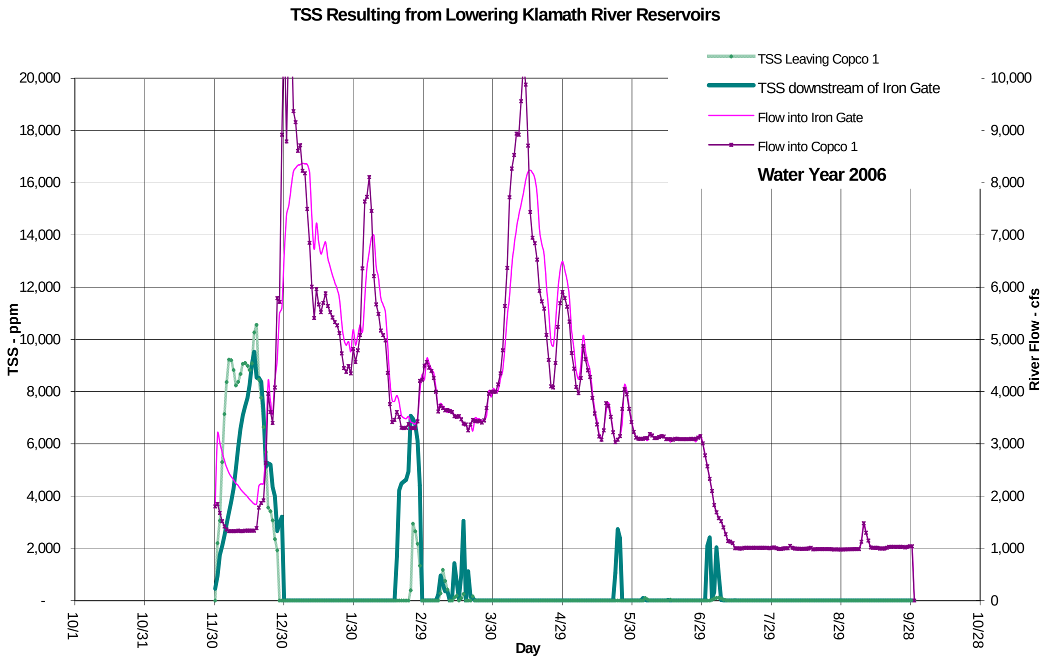

Figure 1 High Flow Year - Start Lowering in December

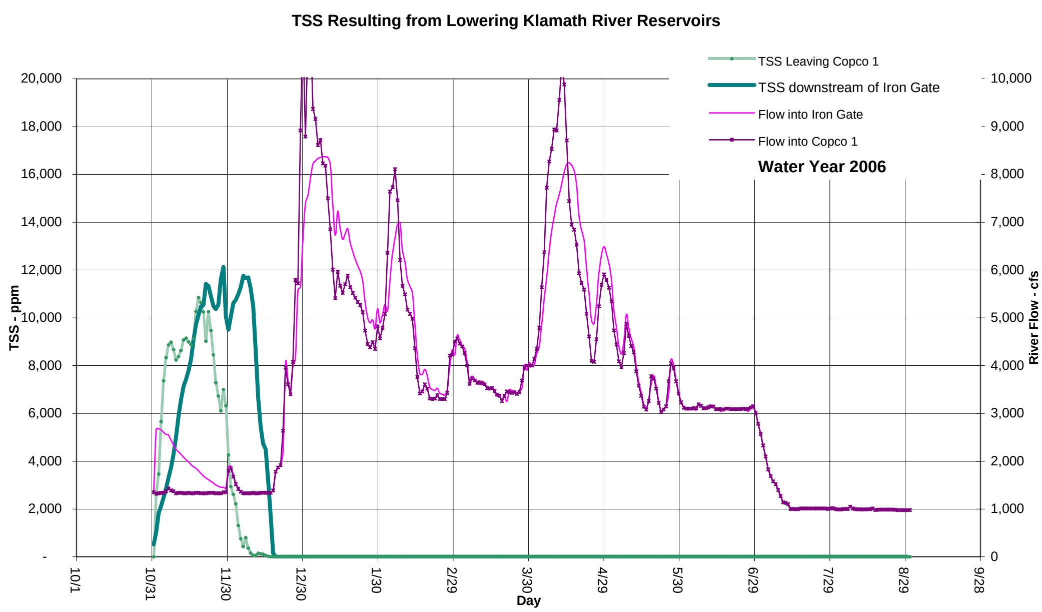

Figure 2 High Flow Year - Start Lowering in November

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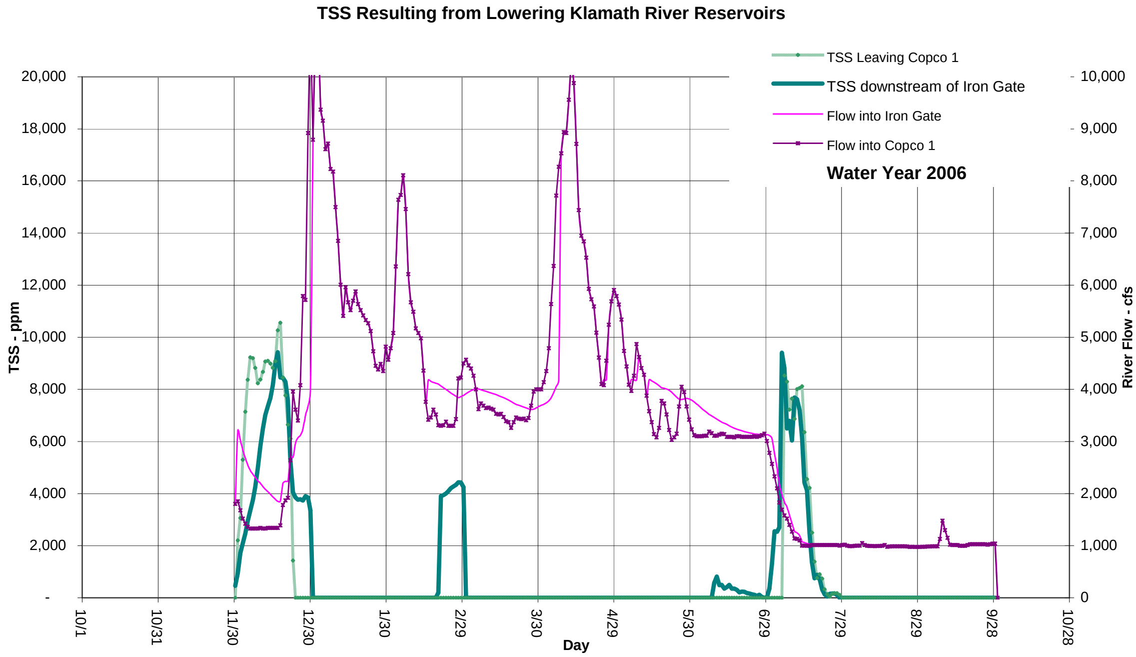

Figure 3 TSS in High Flow Year with Smaller Cocpo1 Outlet

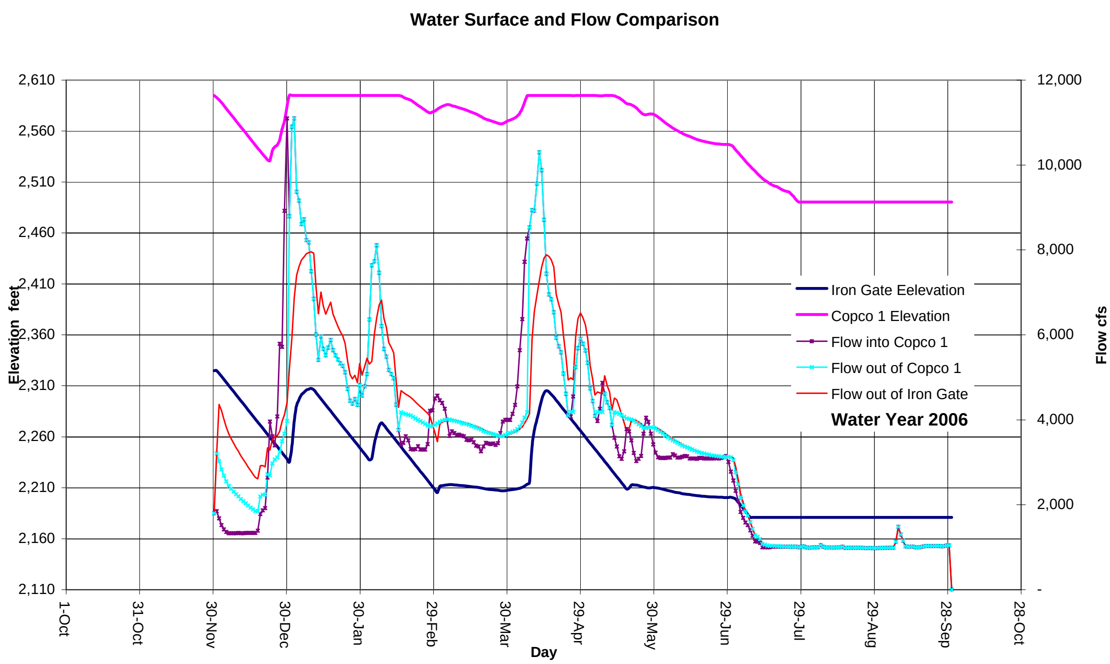

Figure 4 Water Surface and Flow in High Flow Year with Smaller Copco 1 Outlet

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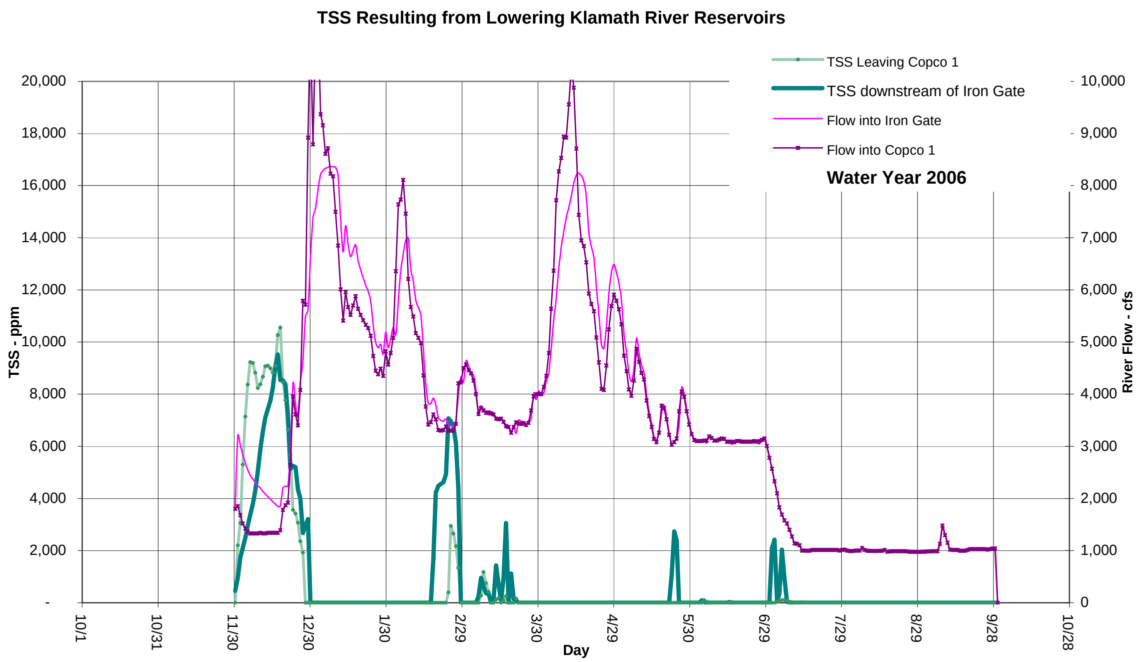

Figure 5 High TSS in Flow Year with Larger Cocpo1 Outlet

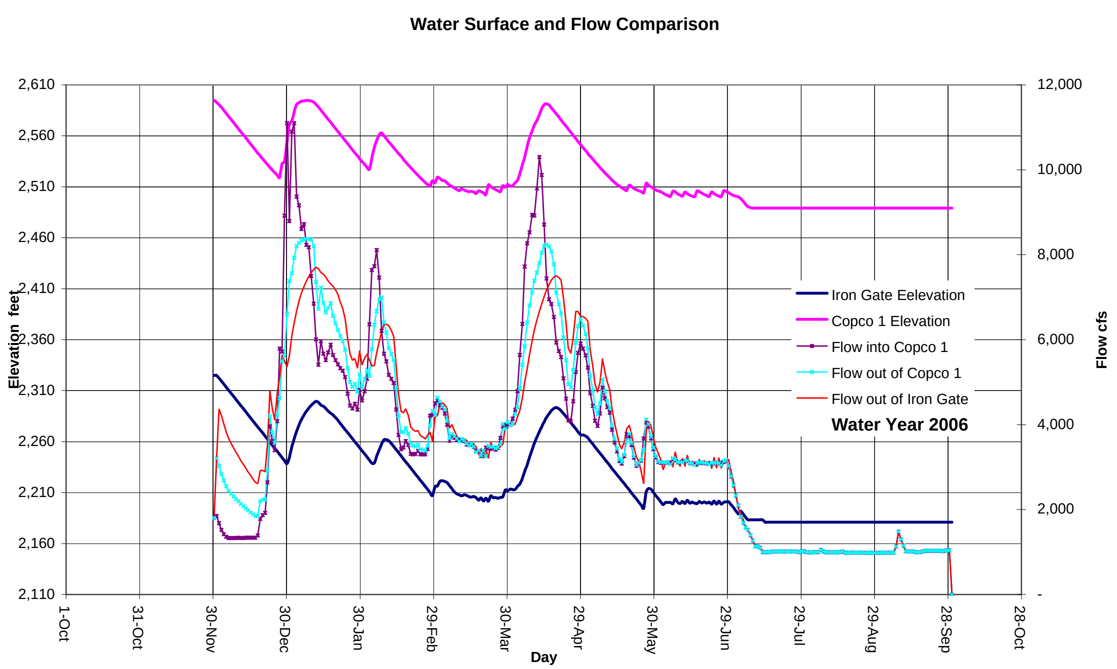

Figure 6 Water Surface and Flow in High Flow Year with Larger Copco 1 Outlet

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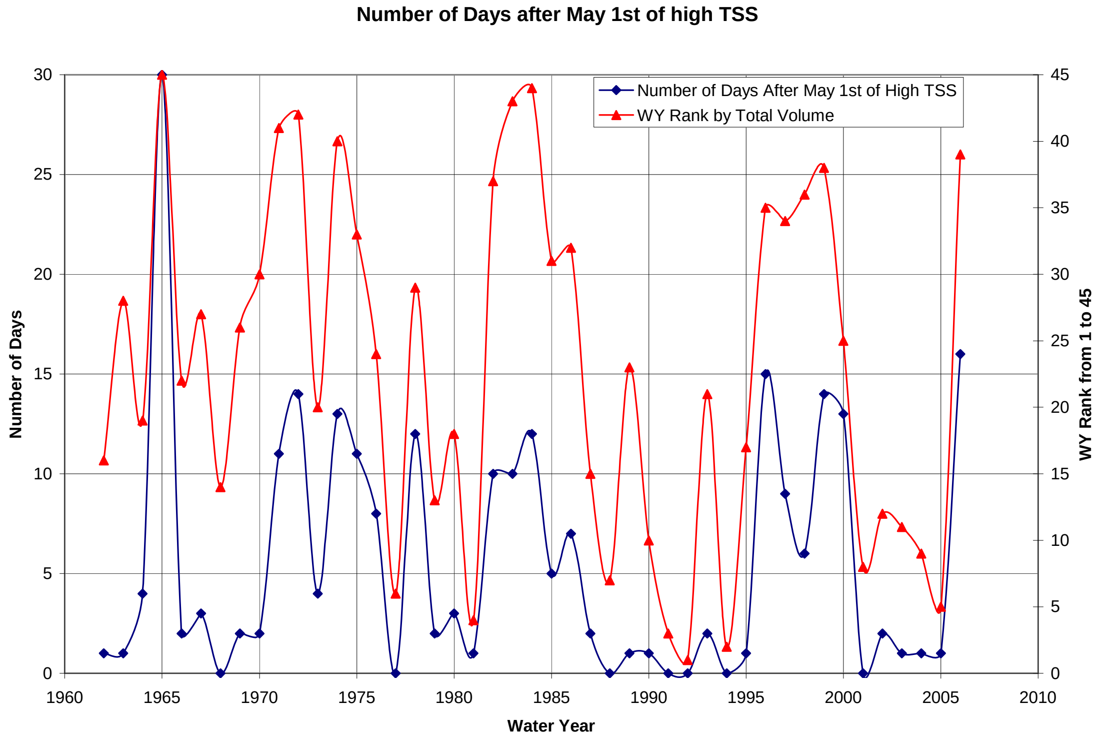

Figure 7 WY Rank vs. Number of Days of High TSS after May 1st

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Results from High Flow Years

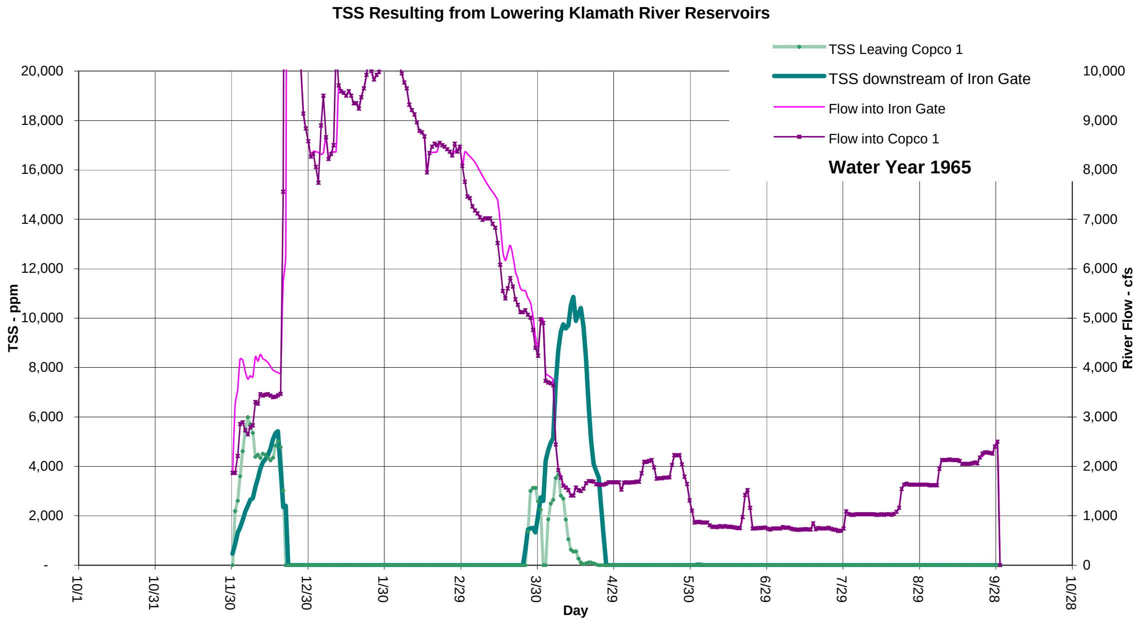

Figure 8 High Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

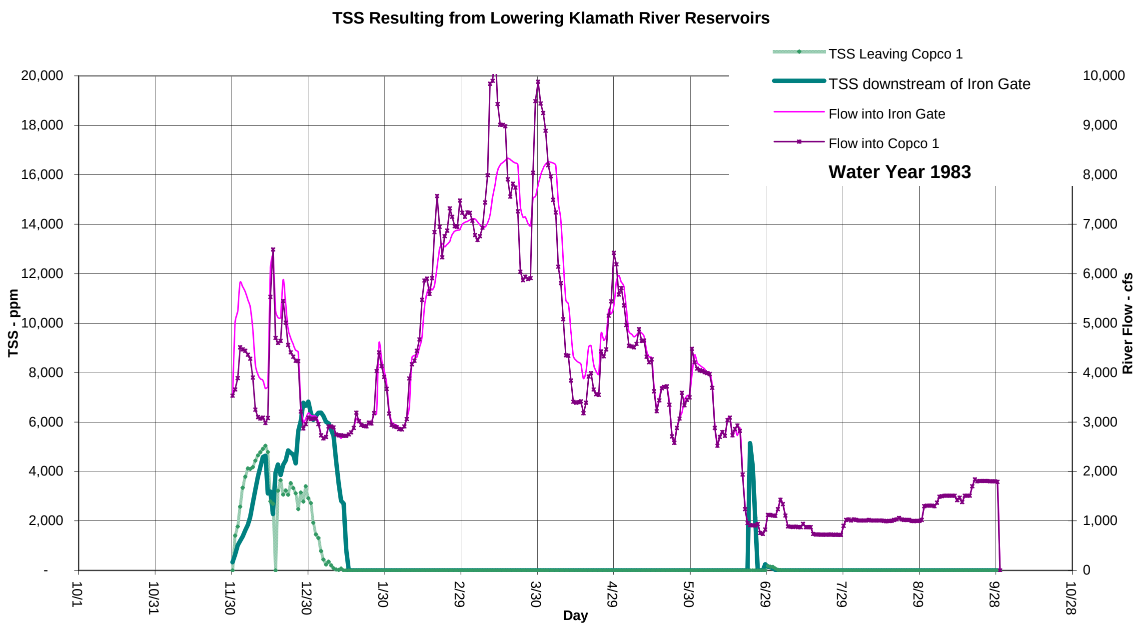

Figure 9 High Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

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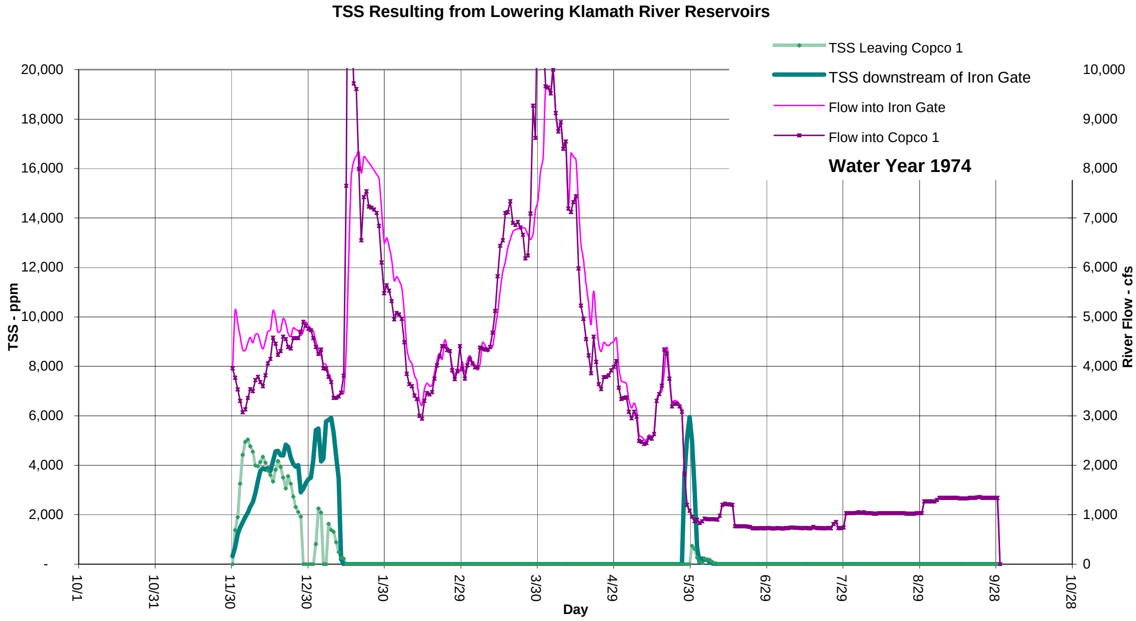

Figure 10 High Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

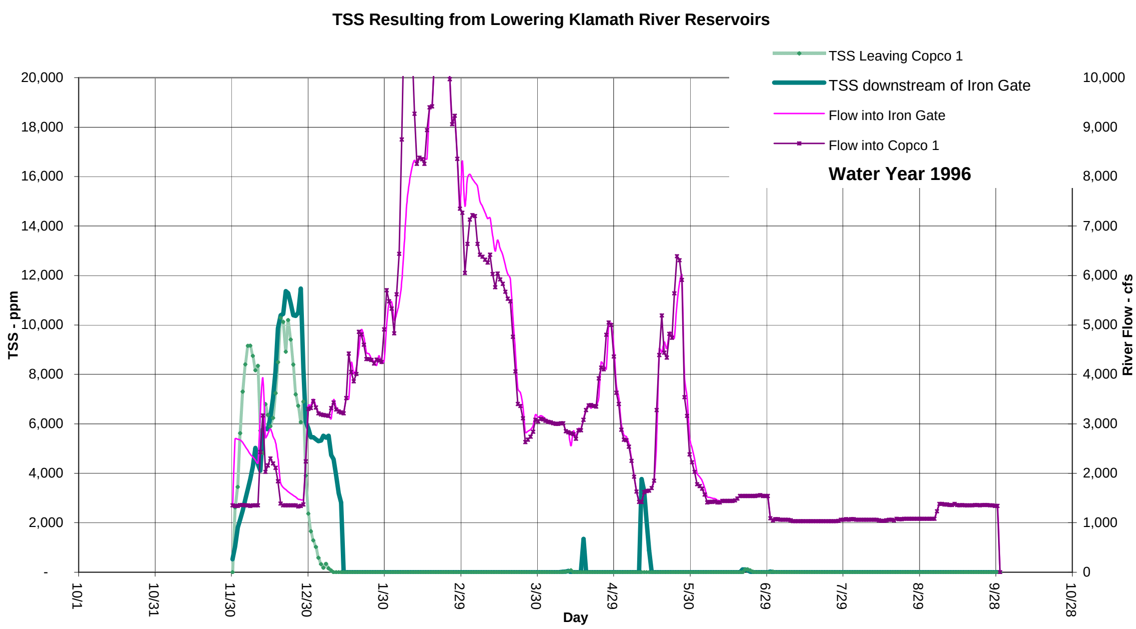

Figure 11 High Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

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Results from Average FlowYears

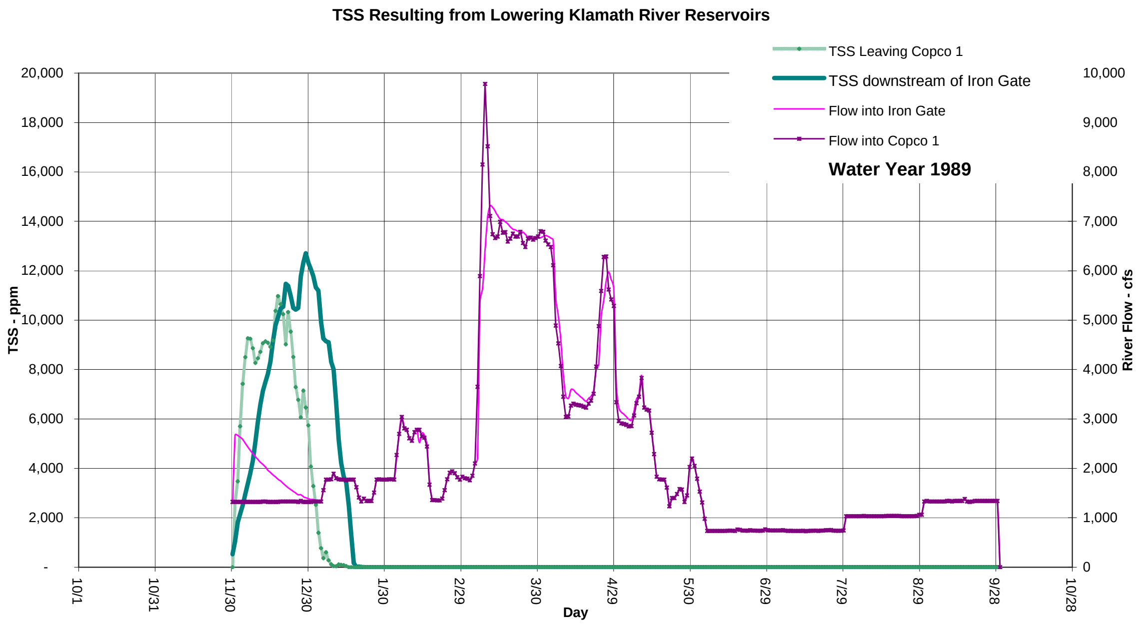

Figure 12 Average Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

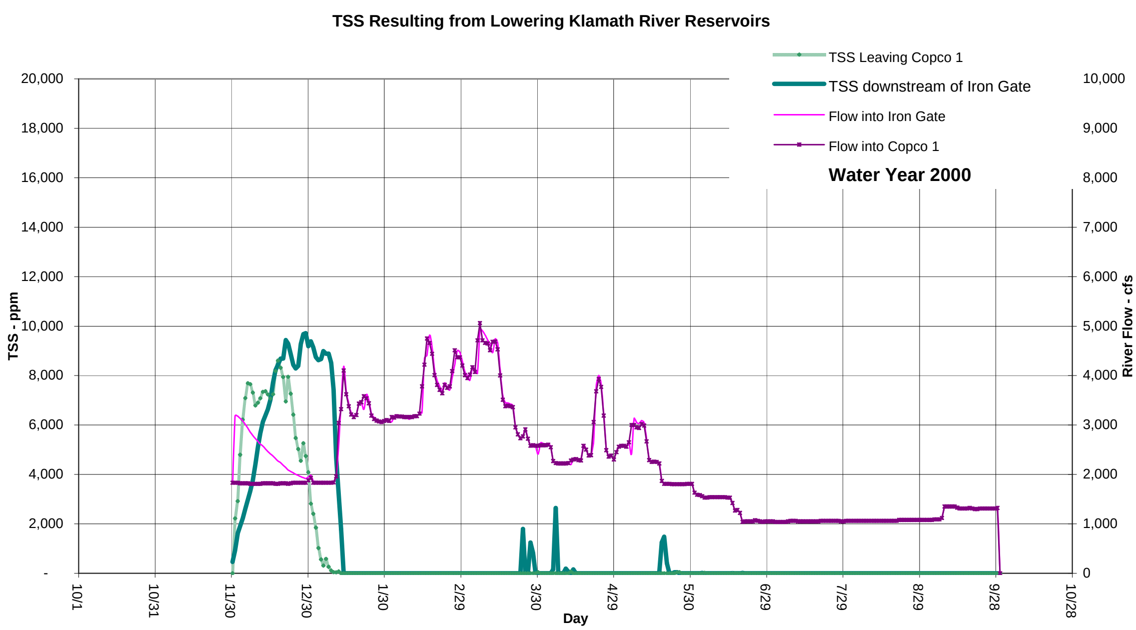

Figure 13 Average Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

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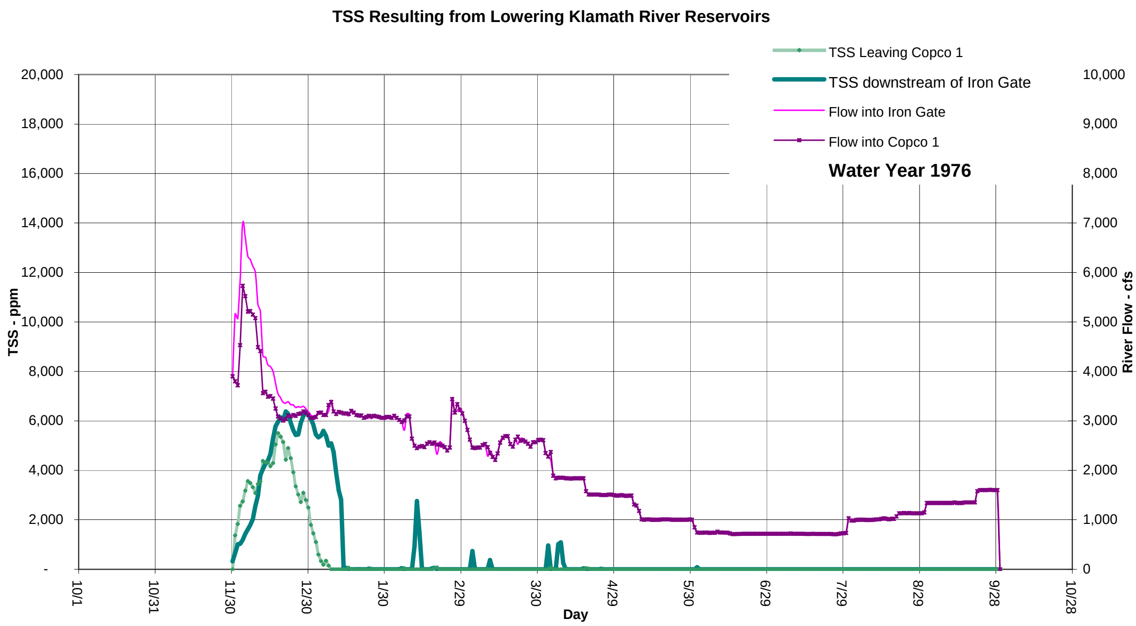

Figure 14 Average Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

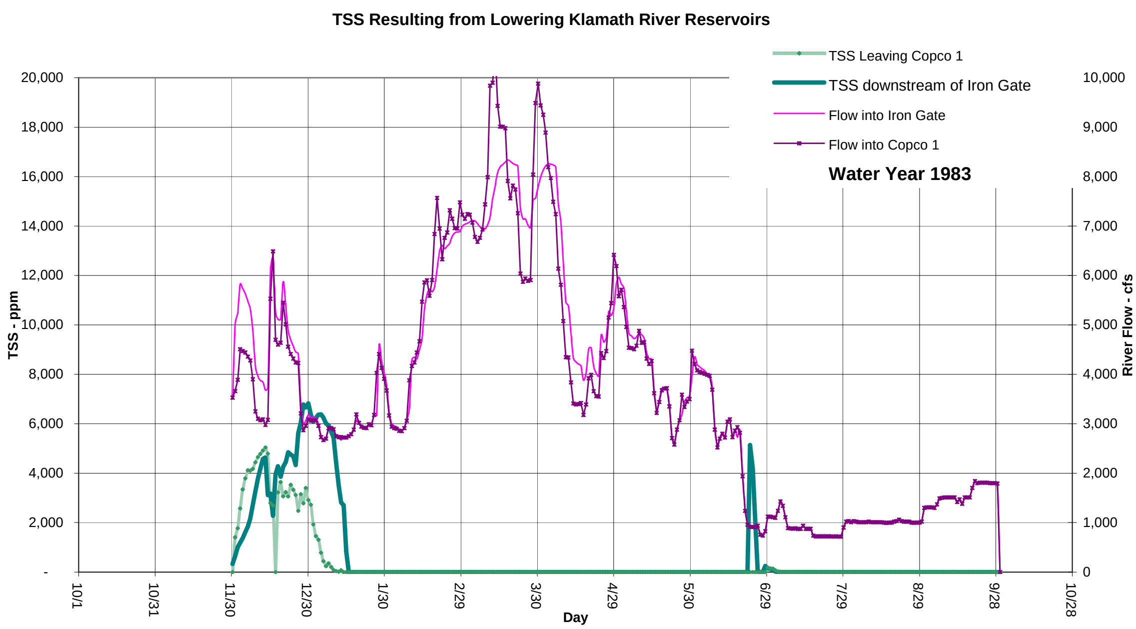

Figure 15 Average Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

Results for Low Flow Years

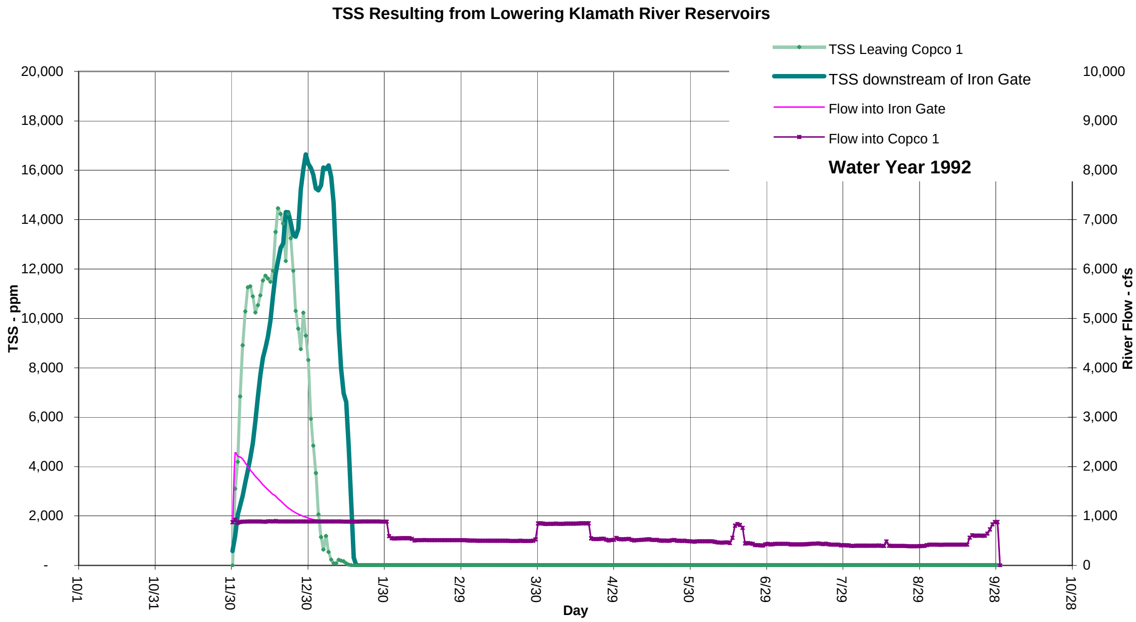

Figure 16 Low Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

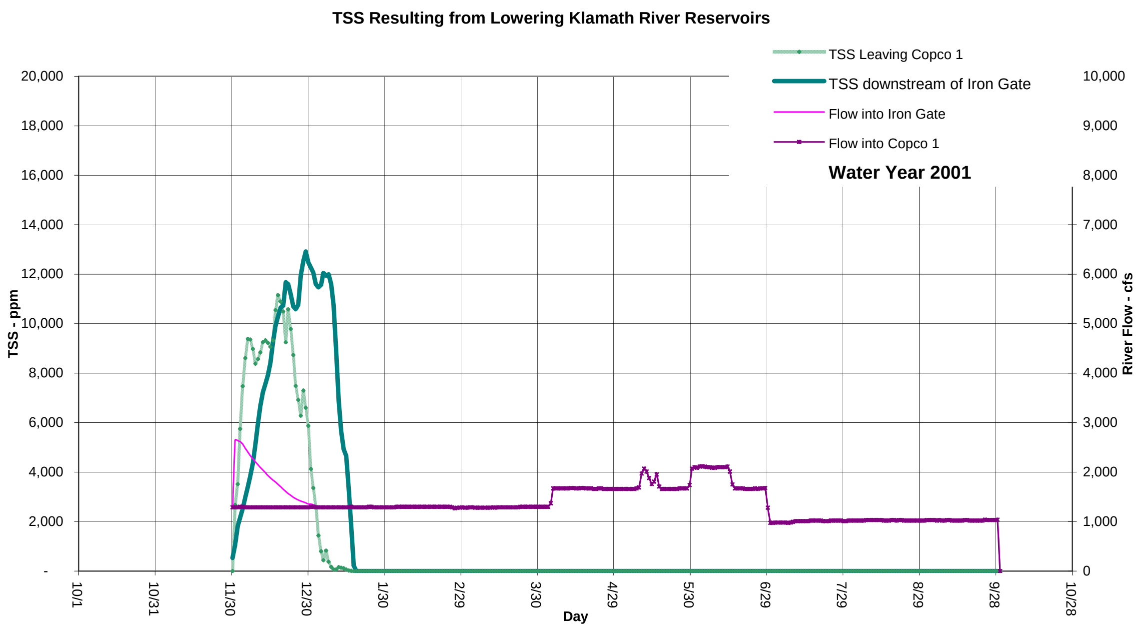

Figure 17 Low Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

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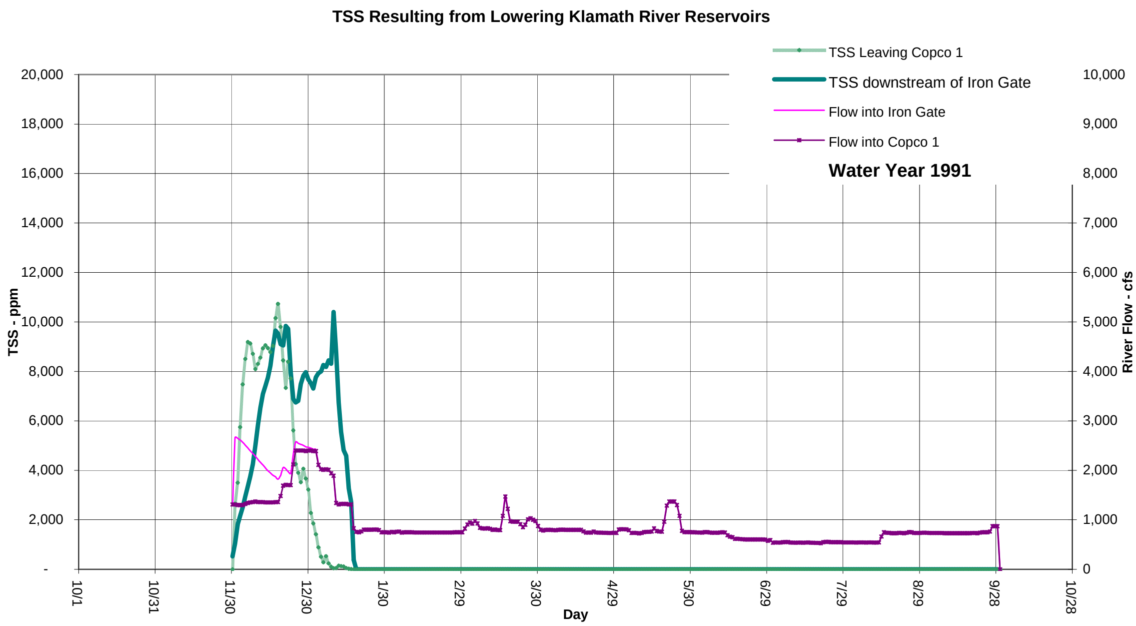

Figure 18 Low Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet

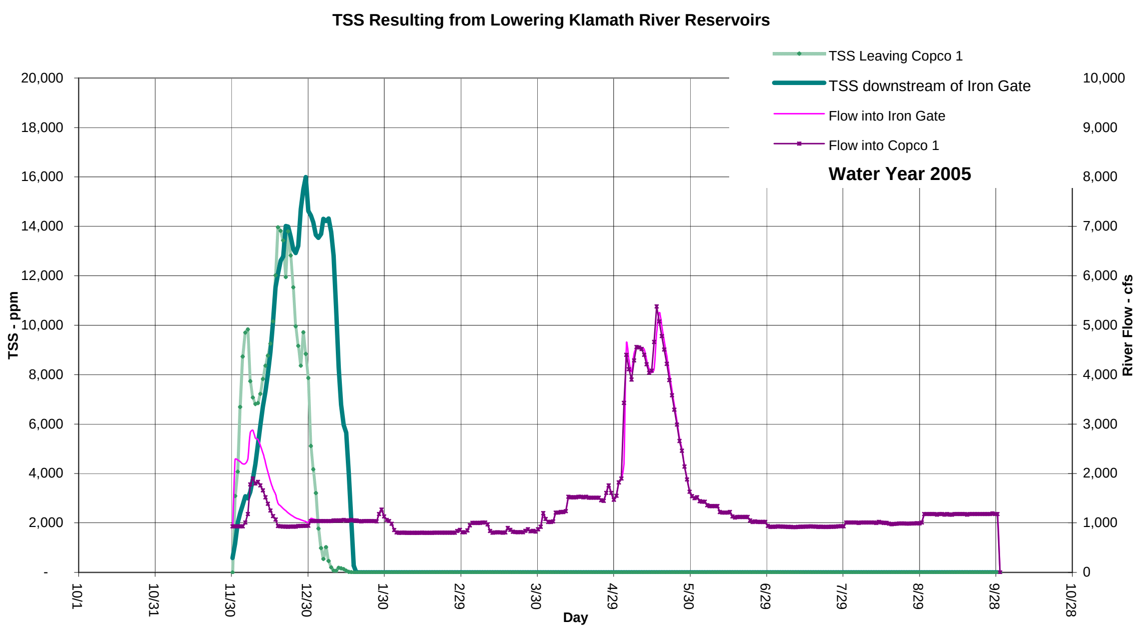

Figure 19 Low Flow Year - Lowering Rate 3 Feet per Day – Large Copco 1 Outlet